

Spectrally Enhanced Lighting

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AfterImage + space

GovEnergy
August 11, 2009
Providence, Rhode Island

The Sky as Inspiration

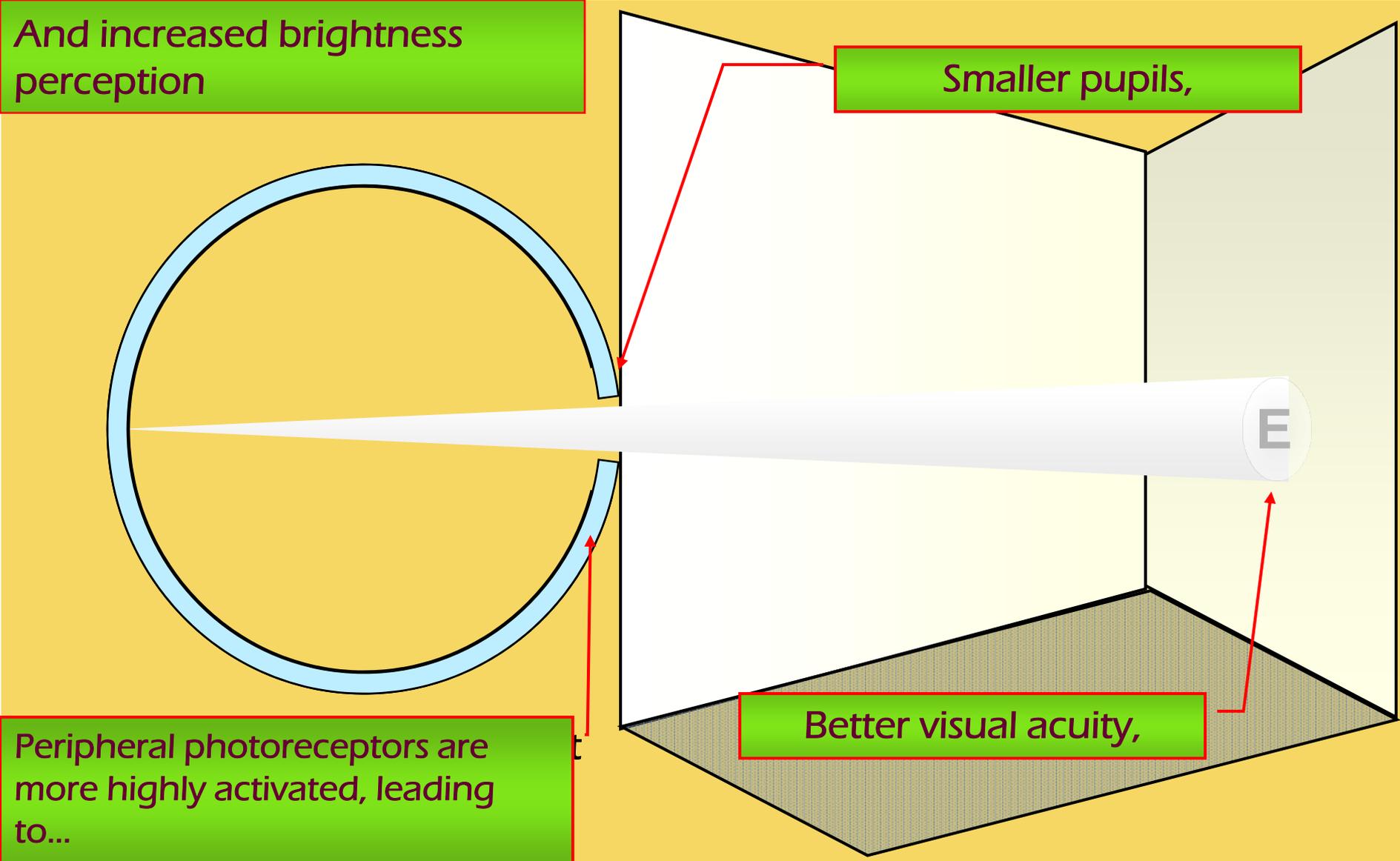
The color of light has inherent qualities that have not been completely understood: all we need to do is look to the sky!

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

**Using Light with more blue,
like the sky:**

- Improves Visual Acuity
- Increases Brightness Perception
- Affects Circadian Rhythm

How Spectrum Affects Vision & Perception



Can We Use Spectrum in Lighting?

Here's a Practical Question:

- What happens when we increase light levels?
 - *Pupils get smaller, spaces seem brighter, and we see more clearly...*
- What happens when we add blue to the light (but don't increase the light level)?
 - *Pupils get smaller, spaces seem brighter, and we see more clearly...*

Yes We Can!

Is adding blue to a light source like increasing the light level?

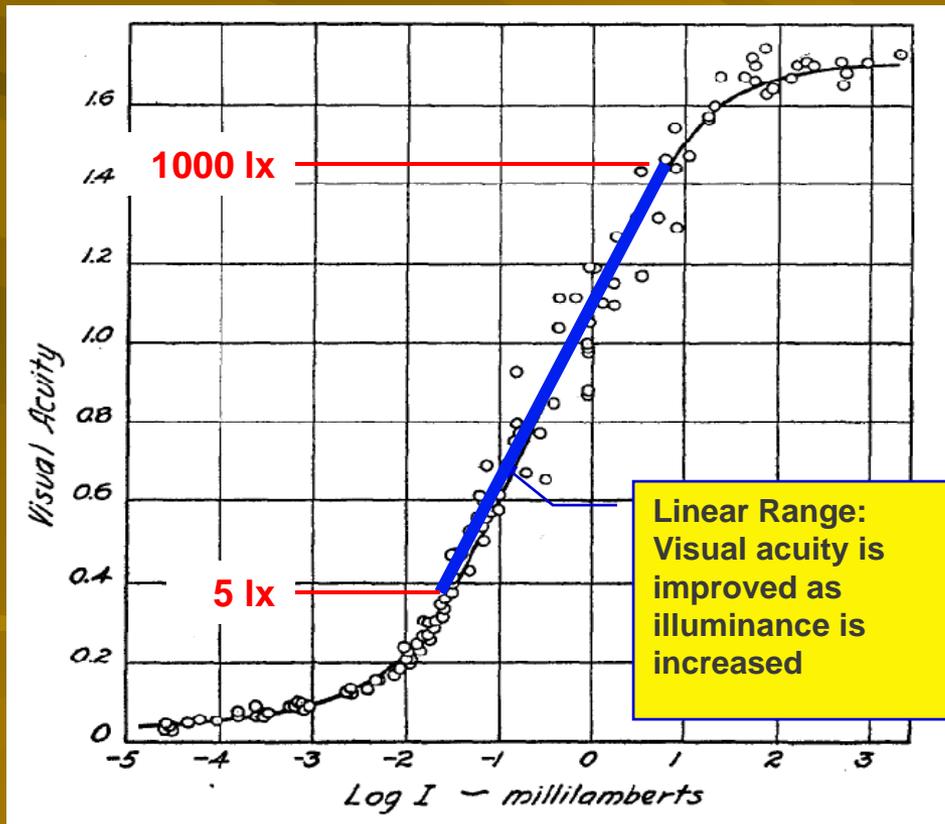
YES

- *Under the following conditions:*
 - *Full Field of view*
 - *Illuminance range of 5-1000 Lux (.5-100 fc.)*

*Enhancing the spectrum of light to optimize visual effect is called “**Spectrally Enhanced Lighting**”*

Light Levels Increase Visual Acuity...

Illuminance Recommendations



Light Level recommendations are based on well-established principle:

Higher light levels increase visual acuity

This is linear *between 5 and 1000 lx*, assuming 70% reflectance.

...and so does Spectrum!

Interior Lighting:

Under the conditions of a full field of view, light with more blue increases visual acuity

- *7 separate studies - from school children to retirees.*
- *Nearly all lighting researchers agree with these findings.*

Interior Light Levels Based on Visual Acuity

IESNA Illuminance Levels:

Category F: 1000 lx

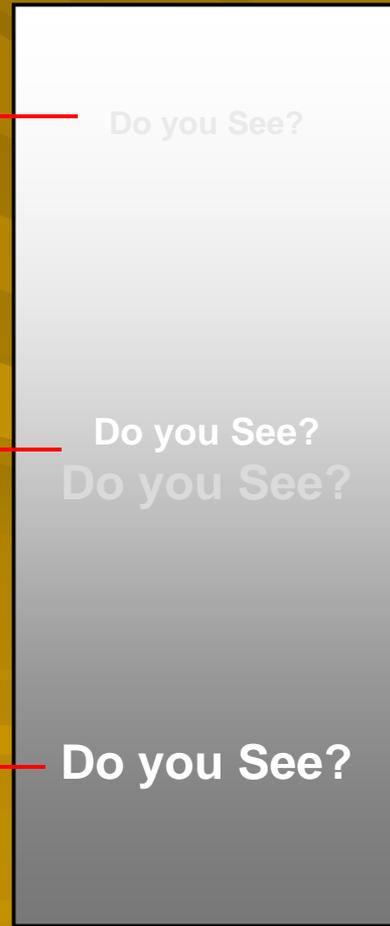
- low contrast, small size

Category E: 500 lx

- high contrast, small size
- low contrast, large size

Category D: 300 lx

- high contrast, large size



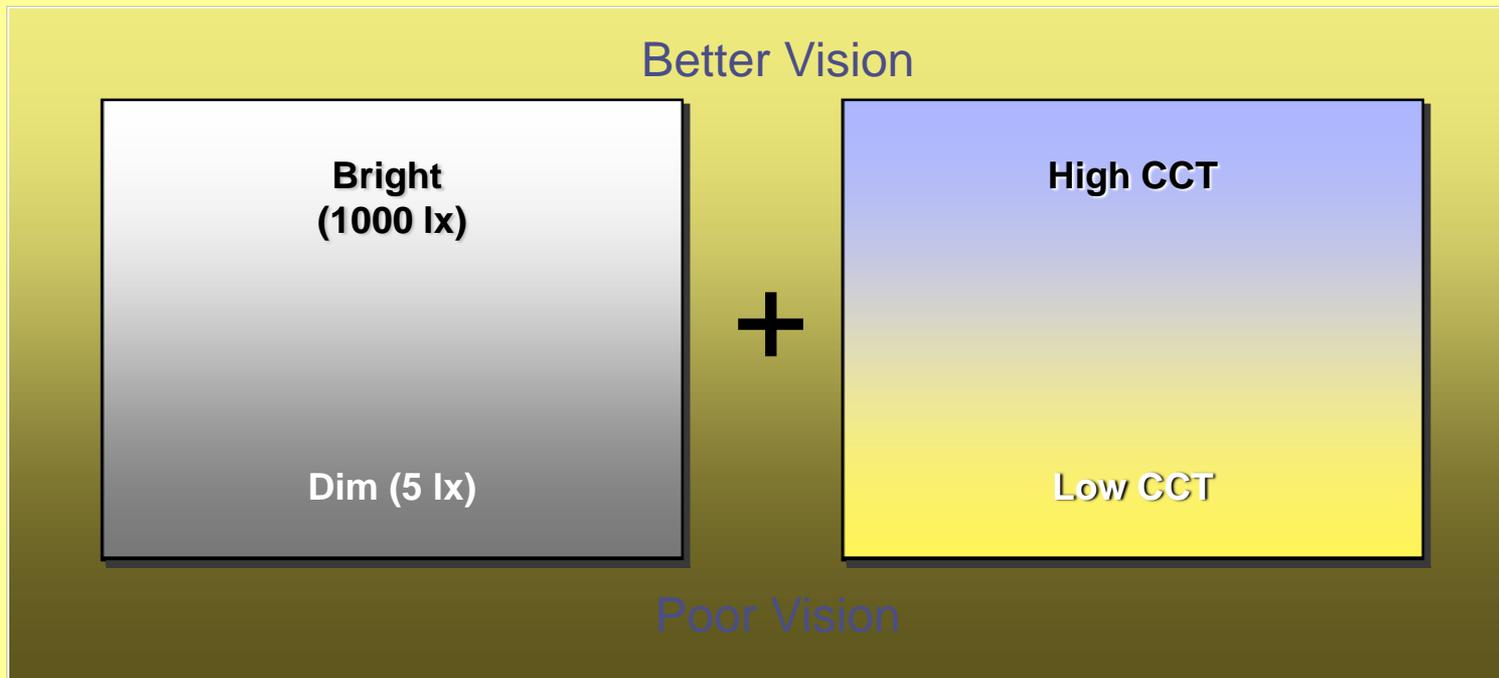
Light Levels for
“Common Tasks”
increase to improve
visual acuity for tasks;

***If Spectrum also
improves visual
acuity, shouldn't it
count too?***

The Concept of Visual Effectiveness

Visual Effectiveness Method:

Combines visual benefits from light level AND spectrum



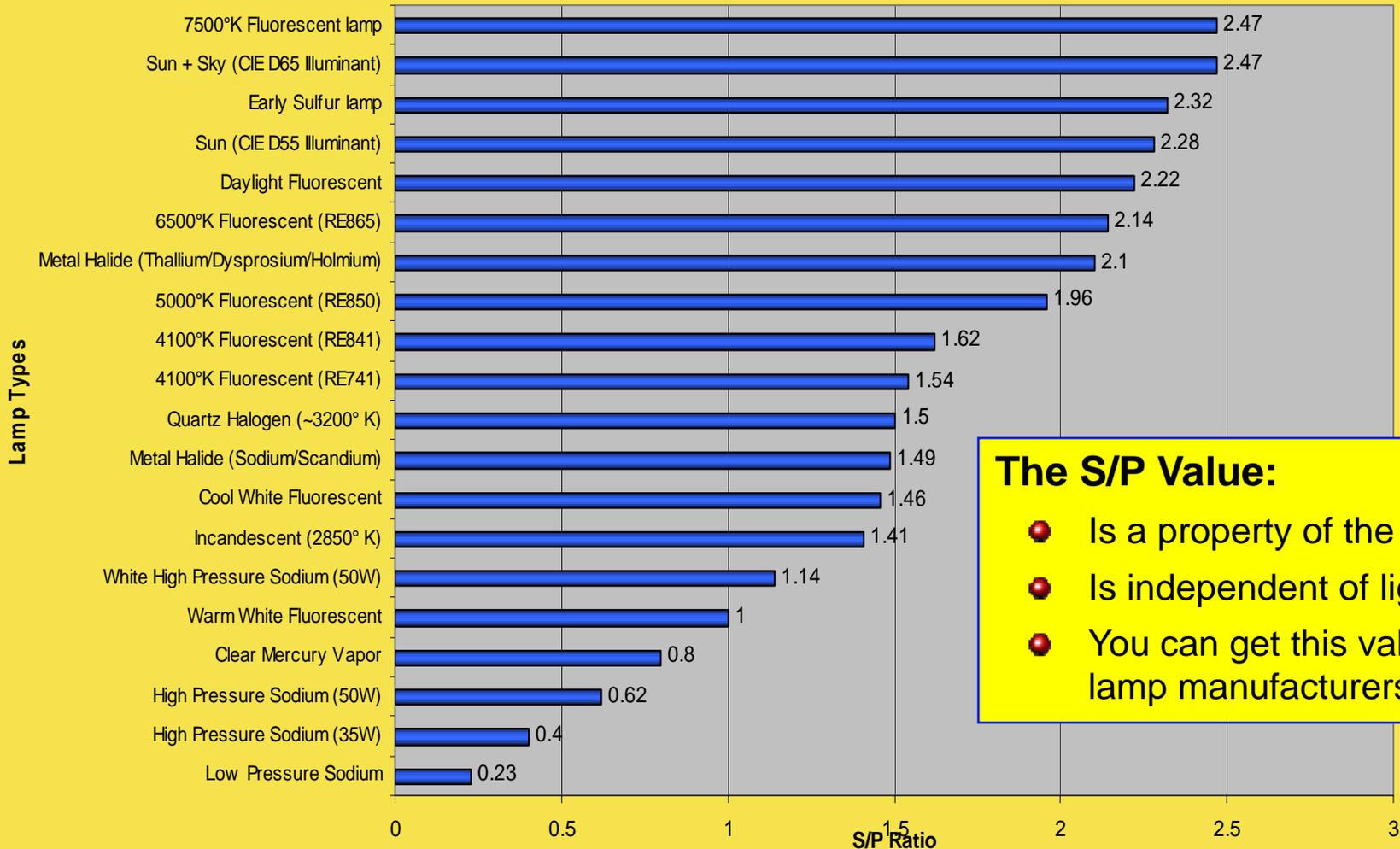
Visual Effectiveness: The S/P Value

What is the S/P Value?

- *The S/P Value is a property of a lamp and is independent of light level (for most sources).*
- *S/P values are used in Visual Effectiveness (VE) formulas to modify lighting calculations.*
- *S/P Values can be obtained from lamp manufacturers*

Visual Effectiveness: The S/P Value

S/P Ratios of Various Lamps

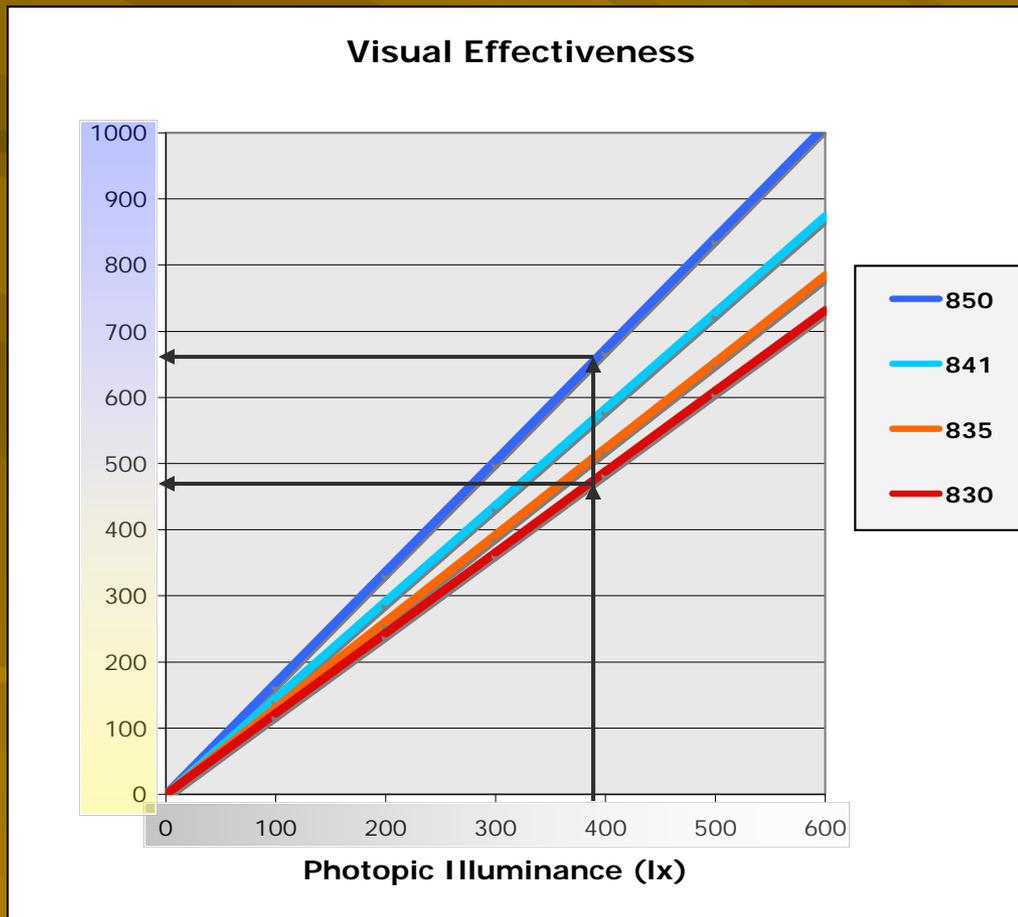


The S/P Value:

- Is a property of the lamp
- Is independent of light level
- You can get this value from lamp manufacturers

The Visual Effectiveness Model

Visual Effectiveness Chart



Adding spectral benefits makes lighting more visually effective:

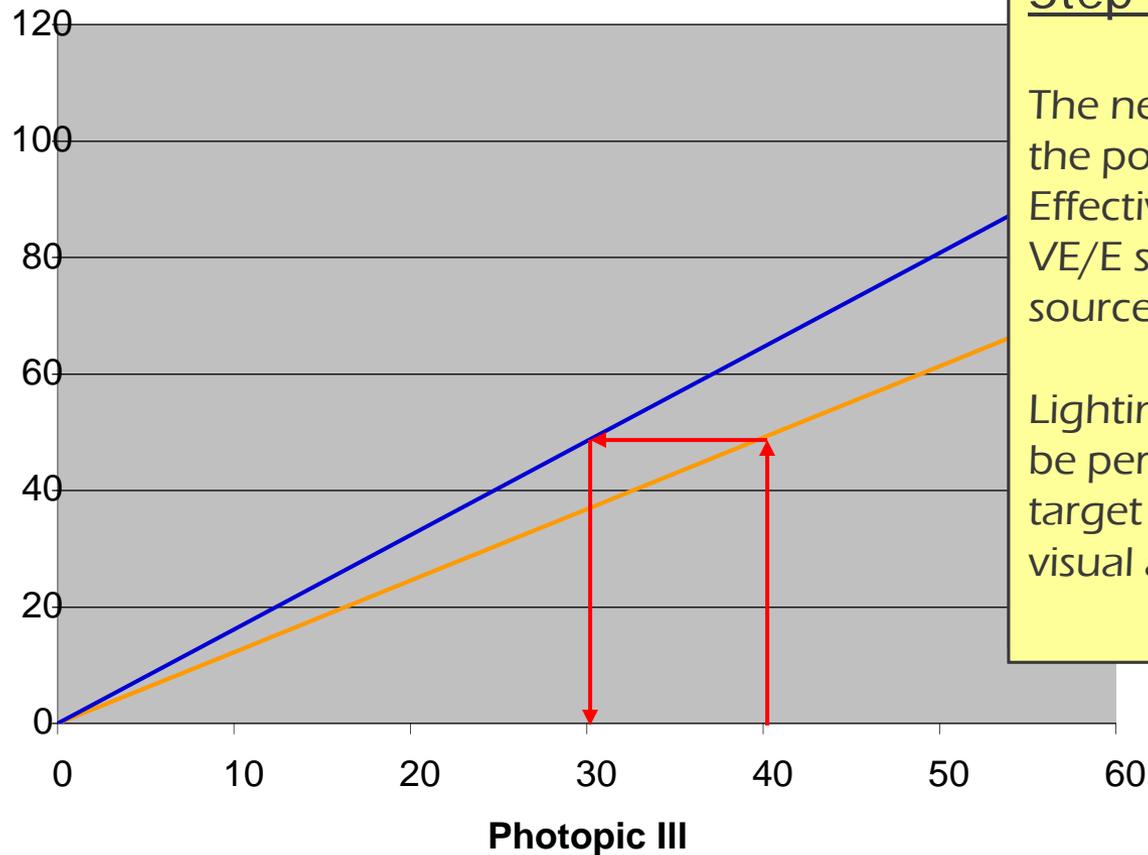
For Visual Acuity, Equal Visual Effective Illuminance is:

$$VEE = P * (S/P)^{.78}$$

Lamp	S/P	VEE @ 400 lx
830	1.29	488
835	1.41	523
841	1.65	583
850	1.95	646

The Visual Effectiveness Model

Visual Effectiveness Method for Determining Light Level



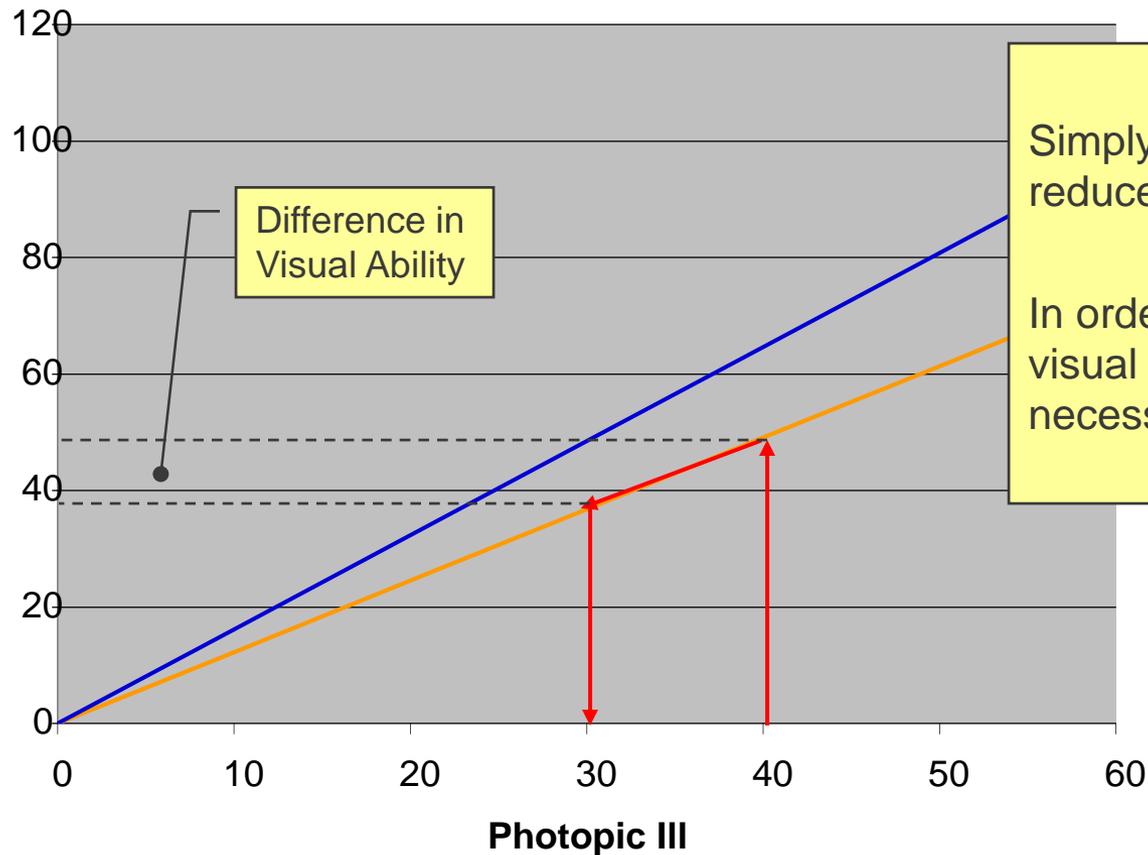
Step 3:

The new photopic illuminance is the point where the Visual Effectiveness value intersects the VE/E slope of the new light source.

Lighting Calculations can now be performed with this as the target illuminance - with equal visual acuity for paper tasks.

The Visual Effectiveness Model

Visual Effectiveness Method for Determining Light Level



Simply lowering the illuminance reduces Visual Effectiveness.

In order to maintain equivalent visual ability, spectral benefit is necessary.

—73
—85

Visual Effectiveness: Conceptual Model



Light Source

Shift Spectrum Toward Blue

Enhances Visual Response

Smaller Pupils

Increased Visual Acuity

Increased Brightness Perception

Reduce Light Level → Save Energy

Equal Visual Acuity

Equal Brightness Perception

Implementing SEL

Step 1: Determine Baseline Lumens:

Lamp Lumens (from lamp Catalog)

x Ballast Factor (from ballast Catalog)

Baseline Lumens

- Ballast factor is a function of:
 - Ballast Type (Instant Start, Programmed Start)
 - Rated Lamps per Ballast
 - Number of Lamps operated on Ballast

Implementing SEL in Retrofits

Sep 2: Determine New Lumens:

- Determine new Lumens for SEL lamp that are visually equivalent to baseline lamps

$$Lumens_{SEL} = Lumens_{base} \left(\frac{(S/P)_{base}}{(S/P)_{SEL}} \right)^{.78}$$

- Get the S/P values from lamp manufacturers; Some list them on their websites/catalogs

Implementing SEL in Retrofits

Example:

- Baseline = (3) 735 lamps, 2850 Lumens ea.; S/P=1.30; Normal Ballast Factor = .86
- SEL Lamp: High Performance 850, S/P =1.95

$$Lumens_{850} = 3 \times 2850 \times (.86) \times \left(\frac{1.30}{1.95} \right)^{.78} = 5360$$

- What combination of 850 lamps and ballasts can be used to achieve this target?

Implementing SEL in Retrofits

Example:

- Target Lumens = 5360
- High Performance 850's = 3100 Lumens ea.
- Two Solutions:
 - Keep 3 lamps: $3 \times 3100 = 9300$: BF = .57
 - De-lamp to 2: $2 \times 3100 = 6200$: BF = .85
- Best Solution: De-lamp and use Normal BF Ballast.

Energy Savings Potential

Increased Efficiency and Energy Savings

Lamp	Mean Lumens (Catalog)	S/P Value	Equiv. Visually Efficient Lumens	Energy Savings
850 3rd	2860	1.95	4815	
F32T8 730	2650	1.19	3035	37%
F32T8 735	2650	1.30	3252	32%
F32T8 830 2 nd	2800	1.29	3415	29%
F32T8 830 3 rd	2950	1.29	3598	25%
F32T8 835 2 nd	2800	1.41	3661	24%
F32T8 741	2650	1.56	3749	22%
F32T8 835 3 rd	2950	1.41	3857	20%
F32T8 841 2 nd	2800	1.62	4079	15%
F32T8 841 3 rd	2950	1.62	4298	11%

Visually Efficient Lumens can be calculated from lamp catalog values and S/P Values.

The potential energy savings gained by using 850 lamps are significant.

Energy Savings Potential

Retrofits Including Updating Ballasts:

Lamp	Ballast Tech	EOL Lumen Maint	EOL Efficacy	Energy Savings
850 3rd	EE IS	92%	145	
F34T12WW	Mag RS	78%	45	69%
F34T12CW	Mag RS	78%	60	59%
F32T8 730	SE IS	90%	82	44%
F32T8 735	SE IS	90%	88	40%
F32T8 830 2nd	SE IS	92%	94	35%
F32T8 830 3rd	SE IS	92%	99	32%
F32T8 835 2nd	SE IS	92%	101	31%
F32T8 741	SE IS	90%	101	30%
F32T8 835 3rd	SE IS	92%	106	27%
F32T8 841 2nd	SE IS	92%	113	23%
F32T8 841 3rd	SE IS	92%	119	18%

Optimum energy savings come when retrofitting with the 850 lamp and new extra efficient electronic ballasts.

40% Energy savings from traditional 735 lamps & ballasts.

SEL Economics

Economics:

- New Construction
 - Immediate Payback; lower installation costs
- Existing Facility, Retrofit Already Planned
 - Immediate payback due to increased energy savings
- Existing Facility, Compared to “Do Nothing”
 - Retrofit T12's: Payback is 1-1/2 Years
 - Retrofit T8's: Payback is 3-4 Years

Achieves Goal for Lighting Power Density

SEL + Premium Ballasts:

- Meets target goal of 40% reduction of ASHRAE 90.1-2001 LPD's
- For Offices, typical LPD's are below .75 W/sq. ft. - lower with task/ambient lighting

SEL is the easiest way to comply with the most stringent energy codes

Avoid Low-Wattage Lamps

Use 32-Watt T8 Lamps:

- Low Wattage T8 lamps (30, 28, 25 Watts):
 - Requires specific ballasts
 - Require warmer temperatures (AC diffusers)
 - Have limitations on remote wiring lengths
 - Long warm-up time (bad for conference rooms)
 - Can't be dimmed

32-Watt T8's assure permanent load reduction - low wattage lamps do not!

SEL - Key Points

It's Simpler... Really!

- *No Special Equipment Necessary*
- *Reduced Materials Cost*
- *Reduces Energy AND Demand Load*
- *Is available NOW*

A Common Question - Will People Like It?

The “Bias” Against High CCT Lighting

- In the United States, many lighting designers believe that people prefer warm colored light.
- This is a learned belief; lighting textbooks often cite a 1930's study claiming this preference - *this has been discredited many times over the last several decades.*
- This warm-colored light preference is not found in many other countries.

Testing SEL in Real Applications

- **2001: 7 Buildings, 300,000 square feet**
 - Informal study using 850 lamps: NO objections to the color of the lighting, even with lowered light levels.
- **2004 UCOP Study**
 - Formal Study. Compared 850 vs. 835; Demonstrated Occupant acceptance of 850 under lower light level.
- **2006 Field Study (with PNNL)**
 - 3 Buildings completely retrofit with 850 lamps and standard ballasts; demonstrated equal occupant satisfaction between pre-retrofit lighting and SEL.

Ideal Solution for Office Spaces

Low CCT Parabolics to High CCT Indirects



Before

During

After

SEL Lighting is an energy saving and high quality lighting solution.

Widespread Acceptance - SEL Works!

Companies/Institutions using 850 lamps as their standard:

- Pacific Gas & Electric Company
- San Diego Unified School District
- Cities of San Diego and Oakland
- Counties of Napa and San Mateo
- Port Hueneme
- Amtrack

Our experience has shown consistently high satisfaction with (850) Spectrally Enhanced Lighting

The Preference: Be More Like Daylight

And Why Not...

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

The 850 lamp has a high CRI and is much closer to daylight than most fluorescent lamps.

A common comment from occupants:

“The old lighting seems “dirty” compared to the new (850) lighting.”

Thank you for your time.

Questions?

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For more information, see:

www.eere.energy.gov/buildings/tech/lighting/sel